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DATA-REDUCTION TECHNIQUES FOR MULTIPLE-PLATFORM RADAR INTEGRATI--ETC(U)

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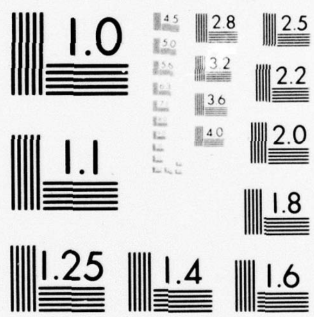

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Data-Reduction Techniques for Multiple-Platform Radar Integration

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A means of sending only the "best" raw detections from radars to update a track is considered. A specific error-filtering concept and method of implementation are introduced. The method depends on comparing the last three raw detections with the current raw detection under test to determine if it will significantly aid the track. In addition the method does not require any additional information be sent over the channel for its implementation. Finally, track updating using range and range rate from at least three noncolocated radars is considered. This method would require little information to be transmitted on the channel, but it is useful only when certain criteria are met. Combinations of both methods may provide the best solution.

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DATA-REDUCTION TECHNIQUES FOR MULTIPLE-PLATFORM RADAR INTEGRATION

INTRODUCTION

A critical area in integrating radars from one platform to another is the transmission of the data over a communication link. A previous report [1] considered this problem. In that report it was argued that the best means of updating the tracks was to use all the detections from all the radars. However this philosophy would place an enormous burden on the communication links and data processors. It was argued that excellent tracking could be obtained by using a small selected set of raw detections which contain the most information. By use of this concept a large number of tracks can be updated, yielding good results with a modest amount of information sent over the communication system.

Three distinct data-reduction techniques that in practice are operated in conjunction with each other were considered in Ref. 1: data compression by using differential positions, time filtering, and error filtering. The error-filtering concept was introduced and described in Ref. 1, but no implementation was found. The present report will briefly review data compression by using differential positions and time filtering and their implementations and then will introduce a means of implementing the error-filtering concept.

Since Ref. 1 was written, a closed-form method of obtaining a target position from range-only information from three noncolocated radars was obtained [2]. Reference 2 suggests using range-only information to update tracks from noncolocated radar data. This concept will be explored, and the possibility of using both raw detections and range information in concert will also be considered.

RAW-DETECTION TRANSFER

Since the data-reduction techniques and the reasons for them were discussed previously [1], this section will only briefly review them. The proposed implementation of the concept of data error filtering is incorporated into the discussion. Finally a performance measure is discussed which can be used with the data-error-filtering concept.

General Data Flow

The basic data flow over the link could be implemented as follows. The platform controlling the track transmits a track number, predicted position, velocity, time, covariance matrix of errors, and threshold (along with any other parameters not yet defined) with a recirculation time of around 4 seconds. The participating platform updates the track to the current time and correlates the track with its previous detections. However not all the detections which correlate are sent over the link. These are filtered as follows.

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Time slots are assigned to each track number, and two conditions must exist before a detection is sent over the link filling this time slot: that no other platform has placed a detection in this time slot and that the measurement error defined subsequently is below the threshold set by the platform controlling the track. Otherwise the correlated detection is discarded. The first condition limits the data rate to the time-slot width and ensures a reasonable spacing in the data. The second condition ensures that the detection is of at least a certain quality before it is sent over the link. When the remaining detections are discarded, the data going over the link are limited in number and are the best data available to update the track. Finally no extra information needs to be sent over the link (except possibly the threshold) to perform this filtering action, since the remaining data are necessary for other functions.

The participating platform, having a correlated detection and meeting the two conditions, transmits track number, differential positions, time, detection covariance matrix, and quality. The platform controlling the track uses this information (except for quality) in updating the track. The quality can be used for error detection on the communication link over the two-way path. The correlation is performed at the participating unit, and a certain quality (defined later) is obtained. The platform controlling the track can also perform the correlation upon receiving the detection to see if the same quality is obtained. If not, an error has occurred somewhere on the two-way path, and the detection is discarded.

There are a number of variations of this basic data flow. A given track may be assigned two sets of time slots, the first using a low threshold to ensure data (even though not that accurate) and the second using a high threshold for only really accurate data. Additional constraints may be placed on acceptance of data. For example grid-lock could be required between transmitting units at both ends before a track is used for correlation on the participating unit or update is accepted from the participating unit. We will next consider the error measures and the thresholds.

Error-Filtering Criterion

The concept of error filtering is to select the "best" data (errors below a certain threshold) in each time slot for transmission over the communication link. The best data for updating the tracks are obtained from observing the past time history of raw detections. We arbitrarily define the last three detections as our reference. In radars the range estimate is usually quite accurate and the angle measurement is fairly inaccurate. The best data are those based on ranges that were crosshaired on the target. The error-filtering criterion is constructed by computing the best estimate of the target position using one's own current raw detection with each of the three preceding raw detections associated with the track.* If the estimated covariance-matrix error-ellipse size is reduced for each

*This does not quite make sense, because the detections occurred at different times. However, since the covariance matrices change very little over this short interval of time, the covariance matrix of the estimate is quite accurate even though the actual-position estimate is poor.

of the last three detections, the raw detection is a good one to use to update the track, because it tends to triangulate the target's position in range with the other detections. This criterion also insures that close-range detections which have good angle estimates will be transmitted over the link. We will now consider the specific criterion.

The best estimate $\hat{X}$ of the target's position using one's own current measurement and other unbiased data points (previous raw detections) is given by the least-squares estimate:

$$\hat{X} = \left[\sum_{i=0}^{1} R_i^{-1} \right]^{-1} \sum_{i=0}^{1} R_i^{-1} X_i, \tag{1}$$

where R_0 is the covariance matrix of the radar measurements (range bearing and azimuth), R_1 is the covariance matrix of the preceding raw detection, X_0 is the position of the measurement, X_1 is the position of the preceding raw detections, and $\hat{X}$ is the estimate of the position.

The covariance matrix describing the errors in the estimated position is

$$\hat{R} = \left[\sum_{i=0}^{1} R_i^{-1} \right]^{-1} . \tag{2}$$

Equation (1) is of no consequence in the subsequent discussion, since the measurements are taken at different times and are biased. However, if the measurements would have been taken at the same time, the covariance matrices would have changed very little. Consequently Eq. (2) is nearly correct for the covariance matrix of the estimate. The significance of Eq. (2) can best be illustrated with an example. If the error ellipse of one's own measurement is small in the X direction and that of a previous raw detection is small in the Y direction, then the error ellipse of the estimate is small in both the X and Y direction. Therefore the two detections in concert reduce the error.

The calculation to set the threshold can be simplified as follows. The estimated covariance matrix is rotated by P and diagonalized:

$$D = P \hat{R} P^T . \tag{3}$$

Since D and $\hat{R}$ are similar matrices, they have the same eigenvalues, which are the diagonal elements of D. These are computed by

$$\left| \hat{R} - \lambda I \right| = 0. \tag{4}$$

This is simply solved as a cubic polynomial. The eigenvalues are also the principal values of an ellipsoid. The volume of an ellipsoid in terms of its principal values is

$$\text{vol} \approx \lambda_1 \lambda_2 \lambda_3. \tag{5}$$

Equation (5) can be used as the error criterion to compare to a threshold. If the error ellipsoid volume is reduced below a threshold for each of the previous three raw detections, the detection is a candidate for transmission over the link, because it will significantly aid the track.

UPDATING USING RANGE AND RANGE-RATE DATA

In the previous discussion the raw detections are used to update a track using a Kalman filter or some variation of it. All three dimensions are measured and used in the filter. In this section we will consider using only the range information for tracking.

For example, assume that at least three platforms are transmitting ranges and range rates. By predicting all of the ranges ahead to the same instant, one can find the target's position using a simple closed-form technique [2]. This procedure yields positions which can be used to develop a track. The system could be operated much as before. The number of platforms reporting ranges and range rates is limited by time filtering. Error filtering can also be used to insure good platform orientations. Since the covariance matrices for the technique in Ref. 2 have not been worked out, no specific error criterion is given. The problem with using only ranges and range rates is that there may not be enough platforms with good orientations to track the target in order to obtain good results. Furthermore a local track is required at each of the three platforms to obtain range rate, and if the range rate is in error, the positions found by triangulation will also be in error.

Two modes of tracking could be used. The first one would use raw detections to update the track as previously described, with the additional provision that range rates be sent along with the raw detections. A second mode could switch to range and range-rate data only, which will yield accurate tracks with few data when the circumstances are favorable. However precise results and concepts are not yet available.

SUMMARY

The basic methods of transmitting only the "best" raw detections over the communication link were reviewed. A means of error filtering was incorporated into the discussion. An error-filtering criterion was introduced which depended on the error in one's own current raw detection and the previous raw detections. Finally the concept of using only range and range-rate information for updating the tracks was considered. This method would require little information to be transmitted over the channel, but it is useful only when certain criteria are met. Combinations of both methods may provide the best solution.

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